are flush with each other so that when they are inserted in the slot 22 they will be flush with the inner end 36 of the slotted plug 2. The plate 23 is shorter than the substrate 18 to provide clearance for making connections to the thermopile and for mechanical protection of those connections.

In Figure 7, details of the thermopile 12 and its connections are shown. The thermopile 12 is a zig-zag pattern of thin film conductors deposited on the substrate 18. The conductors extend between hot junctions 13 and cold junctions 14. In the preferred embodiment, twelve conductors (two marked 37) are made of a first metal, alternating with twelve conductors (two marked 38), made of a second metal. Hot and cold junctions 13 and 14 are formed by sputtering the first metal through a first aperture mask, then sputtering the second metal through a second aperture mask that overlaps the conductors at their ends. In the preferred embodiment the two metals are selected for their large thermocouple potential. The thermopile produces a voltage across its terminals 16 and 17 that is proportional to the temperature difference between hot junctions 13 and cold junctions 14. This signal is also proportional to the heat flowing from the hot to the cold junctions.

In the preferred embodiment terminals 16 and 17 are deposited as thick films on substrate 18, overlapping the respective thin film conductors. Wires 4 and 5 are welded to these thick films, making connections that have good high temperature performance.

Figure 8 shows the ceramic plate 23, a flat rectangular solid of the same material as the substrate. Its function is simply to protect the thermopile from abrasion and other potential sources of damage.

FEATURES OF THE PREFERRED EMBODIMENT OF THE INVENTION

The advantages of the sensor herein described are its ruggedness, environmental tolerance and measurement accuracy. The sensor is rugged because its thin film measuring elements are

deposited on a durable ceramic substrate and protected by a durable ceramic plate. They are protected from abrasion and chemical attack by the plate. The ceramic substrate and plate are themselves protected by enclosure within the threaded plug, which is, in turn, completely enclosed in the material of the mold or other solid object. The only part of the sensor that is exposed to possible damage is its connections, and these can be protected by a shield or plate.

The maximum operating temperature for this sensor is limited only by the thermopile and substrate materials. If platinum/platinum-rhodium thermocouple materials are used, and the substrate is made of Zirconia, the sensor should function well at temperatures approaching 1000°C. Other thermopile and substrate material combinations may be utilized at lower temperatures.

The sensor's measurement accuracy results from a good match of thermal properties among the mold material, the material of the threaded plug and the substrate and plate materials, as well as the good thermal contact in all directions among these three parts. In the preferred embodiment the thin film thermocouples and their interconnections on the substrate do not shunt a significant amount of heat away from the substrate because their mass is so small compared to that of other elements of the sensor. They simply indicate the temperature difference on the surface of the substrate. The substrate, in turn, replicates the temperature distribution in the threaded plug because it is in good thermal contact with the material of the plug along its length. The threaded plug replicates the temperature distribution in the mold body, because it is in good thermal contact with the material of the mold along its length. The net result is a differential temperature measurement that accurately represents the heat flux in the mold body.

If the sensor of the preferred embodiment is installed in a solid material with its axis aligned with the flow of heat, it will indicate the total conductive heat flux in the solid. However, if the axis of the sensor is not aligned with the flow of heat, it will indicate the vector component of heat flux parallel to its axis. Thus, two or more of these sensors may be installed in a solid body with their respective axes at normal or other angles to each other, enabling measurement of the heat